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Minimizing time awaiting training for graduates of the Basic School

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NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

MINIMIZING TIME AWAITING TRAINING FOR GRADUATES
OF THE BASIC SCHOOL

by

Joseph M. Grant

March 2000

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MINIMIZING TIME AWAITING TRAINING FOR GRADUATES OF THE BASIC SCHOOL

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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN MANAGEMENT

from the

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ABSTRACT

Graduates of The Basic School often spend longer than necessary waiting for their military occupational schools to start. Excessive waiting by graduates is the result of a scheduling conflict between Basic School graduation dates and the start dates of twenty-one different schools. This classic scheduling problem results in less available manning for the operational forces. The goal of this thesis is to provide a desktop computer model, based on a linear program, that optimally distributes military occupational specialty quotas to all fiscal year Basic School companies and minimizes the time spent waiting by officers between graduation and the start of their occupational school; while also providing maximum equity of opportunity for all officers to seek any of the twenty-one military occupational specialties. The Minimizing Time Awaiting Training model built in this thesis optimally allocates the annual quotas in an efficient and equitable manner using a Pentium II desktop computer in approximately ten seconds. Numerous model runs yielded a total time savings ranging from a high of forty five man years, to a low of twenty man years.

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I.   INTRODUCTION

A.   BACKGROUND

The goal of United States Marine Corps manpower planners is "to put the right Marine in the right place at the right time with the right skills". Currently, this goal is not met in the area of Military Occupational Specialties (MOS) assignments for graduates of The Basic School (TBS). Manpower planners do not optimally match MOS school seats and start dates with assignment of MOS quotas at The Basic School. As a result, many lieutenants spend an inordinate amount of time waiting to start MOS training. This time awaiting training contributes to undesirable "P2T2" (patients, prisoners, trainees, or transfers). P2T2 is defined as those Marines who are not available for manning in operational units because they are in one of four possible categories: 1) they are in the training pipeline, 2) they are moving to a new duty station, 3) they are sitting in the brig, or 4) they are recovering in a hospital. Large P2T2 means the Marine Corps does not have as many officers available to man its operational units. Any decrease in P2T2 allows a higher level of manning and operational readiness in the fleet.

Currently, Headquarters Marine Corps determines the required quotas for all MOS's each year. For many years, Headquarters Marine Corps (HQMC) assigned MOS quotas perfectly equitably to each Basic School company. TBS conducts six training companies per fiscal year for a total of about thirteen hundred lieutenants. This "equitable" method usually results in the total quotas being divided by six, e.g., a yearly need for sixty communications officers, means each TBS company is given ten communication officer slots. Unfortunately, the military occupational school, USMC Communications Officer School, only conducts two classes per year. Therefore, two-

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thirds of all future communication officers must spend time waiting for school to start. This waiting time results in a delay in arriving to the billet for which an officer is slated. Moreover, the delay causes fleet units to survive without the billet being filled. Or, the delay causes fleet units to extend officers currently serving in the billet beyond their normal assignment time. Extending officers past their normal assignment time can cause higher manpower attrition due to "job burnout". Additionally, the delay creates a negative ripple effect in the manpower system because the officer extended in an operational billet is likely slated to fill another billet elsewhere in the Marine Corps.

HQMC plans in advance for class seats for officers to attend MOS training at other military service schools. Through the normal budgeting cycle, HQMC works with Marine Corps schools and other service schools to determine necessary school seats each fiscal year. Therefore, if a school seat is left vacant due to inefficient assignment, the Marine Corps misses the opportunity for training it has already purchased.

In 1999, HQMC built an Excel based spreadsheet model in an attempt to better match MOS quotas assigned to each TBS company with start dates and seat quotas for MOS schools. The Excel model decreased the number of days waiting for MOS training. But, several weaknesses to the model appeared during its use in decision making. First, the model relies on a decision maker's intuition and experience to guess at possible feasible solutions. Second, the Excel model does not do sensitivity analysis quickly. The decision maker using the model must manually enter an inordinate amount of data for each new scenario. Finally, the model does not utilize the tremendous computing power of desk top computers to systematically find the most efficient solution based on the available data, variables, and constraints.

Efficiency in assignment of MOS quotas to reduce time awaiting training is not the only factor to consider. Another important and relevant factor is a sense of fairness or "equity" of quotas for MOS's. HQMC, as well as the Commanding Officer of The Basic School, require some dispersion or variance of MOS assignments to the six yearly TBS companies. For example, if HQMC requires sixty communication officers, it is not acceptable to assign thirty communication officers each to the two TBS companies that graduate just prior to the start of the USMC Communication Officer courses. Although perfectly efficient, the equity or fairness to the other four TBS companies is unacceptable. Mandating some portion of total MOS quotas for each MOS for each TBS company ensures all officers an adequate chance for assignment to the twenty-one different MOS's available to unrestricted Marine Officers. HQMC believes a feasible solution probably exists that meets both the need for equity and the need for efficiency. HQMC also believes a better computer model could be built that finds feasible solutions, but in a quicker and easier manner than the Excel model.

B.   PROBLEM DEFINITON

A method is sought to distribute annual MOS classification quotas to TBS companies in a way which best meets the needs of the Marine Corps by minimizing the time spent waiting by newly classified officers between TBS graduation and MOS school matriculation, while providing maximum equity of opportunity for MOS selection.

C. SCOPE AND METHODOLOGY

1. Scope

The scope of this thesis involves formulating and solving an optimization problem whose objective functions include two goals. First, minimize the time all officers spend waiting after graduation from TBS until the start of their primary MOS school. The first objective function's goal is "efficiency". Second, maximize equity of opportunity for officers to be classified into MOS's by providing an equal or proportionate share of MOS quotas for each TBS company. The second objective function's goal is therefore "equity". The goals of "efficiency" and "equity" will be combined into one optimization problem to facilitate the exploration of different policy objectives by HQMC decision makers.

2. Methodology

The methodology in this thesis centers around ten steps. Step one is conducting a literature search of similar problems and possible solutions experienced in both the military and civilian business sector. The search involves books, magazines, and theses.

Step two is reviewing appropriate mathematical techniques like linear programming that solve this type of optimization and scheduling problem.

Step three is gathering necessary data. Data includes items like TBS and MOS class sizes, class convening dates, and MOS quotas.

Step four is related to step three. After gathering the known data, determining relevant constraints is next. Determining the constraints of this problem requires discussions and interviews with The Basic School and Headquarters Marine Corps. The

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constraints include the following: number and dates of TBS company graduations, number and dates of primary MOS schools, size of TBS companies, and number of available school seats by MOS.

Step five involves examining optimization software programs that could be used to solve this problem. Ideally, the software exists at both Naval Postgraduate School and Headquarters Marine Corps.

Step six is identifying the costs, either time or financial, associated with P2T2. Identifying relevant costs demonstrates any gain or improvement of a new model over a previously used model.

Step seven is the development of the mathematical formulation for the problem.

Step eight is the actual building of a proposed optimization model using an appropriate software.

Step nine is the running of the model. Running the model several times with different input parameters and variables allows exploration of different possible combinations of "efficiency" and "equity".

Finally, step ten involves checking the model results for feasibility. Additionally, this step allows examination of how much flexibility the model possesses if parameters are changed.

D. BENEFITS OF THESIS

The benefits of this thesis are twofold. First, HQMC receives a vastly superior computer model that enables decision makers to quickly find the number of MOS quotas to equitably assign each TBS company while reducing wasteful time awaiting training.

Additionally, the model will allow decision makers to vary inputs so different policy options can be examined.

Secondly, the model will reduce unnecessary time awaiting training. Ultimately, this means more officers are filling operational billets in the Fleet Marine Force resulting in improved unit readiness.

E.   ORGANIZATION OF THESIS

Chapter I discusses the background of the time awaiting training problem for USMC officers. This chapter also defines why excessive time awaiting training is not desirable. Finally, the chapter discusses the possible benefits and organization of this thesis.

Chapter II examines previous research conducted for similiar scheduling problems in both the military and civilian society.

Chapter III discusses how Military Occupational Specialties are determined and assigned. Additionally, this chapter describes why a computer model is a more desirable means to allocate MOS quotas to The Basic School than previously used methods.

Chapter IV defines this scheduling problem in terms of objective functions, variables, indices, and constraints.

Chapter V examines the old model used to allocate Military Occupational Specialties. This chapter also compares the results of the old model versus the results of a new computer model titled Minimizing Time Awaiting Training (MTAT). The chpater also describes the flexibility of the MTAT model.

Chapter VI contains recommendations and conclusions from the research of this thesis.

II.   OVERVIEW OF RELATED STUDIES

The problem of assigning MOS's at The Basic School in order to meet future MOS class offerings is a classic assignment problem. Similar scenarios in the military and business communities are solved using some form of linear or nonlinear programming. Relevant examples are reviewed below.

A.   RELATED MILITARY STUDIES

In his thesis, Chilson [Ref. 1] develops a model entitled Minimizing Cadet Temporary Duty (MCTDY) to more efficiently assign three thousand newly commissioned Army officers each year from the Reserve Officer Training Corps (ROTC) to their initial assignment. Each new officer is assigned to one of nineteen possible branches (e.g., armor, infantry), each of which conducts a training course entitled Officer Basic Course (OBC). These courses are scheduled at multiple and different times throughout the fiscal year. Additionally, the Army requires approximately eight-hundred fifty of these new officers to serve in one of two possible assignments before attending an OBC. These assignments include either recruiting at the local university for the ROTC unit,or serving as a Camp Lieutenant for a basic or advanced ROTC summer camps. Prior to the work done by Chilson, the Army manually assigned all eight hundred fifty recruiting and camp billets as well as all three thousand OBC school seats. This manual work amounted to approximately six hundred man-hours and resulted in marginally effective assignments.

Chilson develops a mixed integer linear program (MIP). The MIP is solved using the General Algebraic Modeling System (GAMS), to produce a schedule that meets

all requirements. His computer model solves the scheduling problem using a desktop IBM computer in about 73 minutes.

This model successfully accomplishes three important goals. First, the model greatly reduces the time required to schedule cadets to OBC, ROTC, and Camp Lieutenant billets. Second, it reduces travel costs incurred at scheduling conferences for manually scheduling cadets. Third, the model develops a schedule that minimized slack days between graduation and the start of training at OBC. Although no formal cost-benefit analysis was conducted, Chilson approximates savings of nearly $225,000 annually by reducing just one day from the average number of slack days for three-thousand new lieutenants.

Maskos [Ref. 2] develops a computer based multi-objective optimization model to help manpower planners at Headquarters Marine Corps assign Marine recruits to Military Occupational Specialties (MOS's). Using GAMS and a desktop 386/486 personal computer, he solves a multi-objective problem. The objectives include: 1) maximizing the fill of training classes; 2) maximizing the quality of assignments as determined by prerequisites; 3) minimizing total waiting time from initial training (recruit training and School of Infantry) until actual convening of MOS classes; and 4) maximizing expected success of the recruits in each MOS school by matching the required proficiency score of the school with the respective scores of each recruit. This multi-objective problem also had challenging constraints that were difficult to model. Specifically, Maskos had to assign exactly one training class for each recruit. He also had to ensure each recruit met the mandatory prerequisite proficiency scores for the specified class. Additionally, he had to overcome two difficult constraints from

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Headquarters Marines Corps. The first involves a minority distribution policy that mandates minimum and maximum percentages of minorities for training classes. The second involves honoring the commitments to recruits for MOS's that had legally been guaranteed as a condition to joining the Marine Corps.

This large scale optimization problem was far too complicated for linear programming techniques. The constraints cause infeasible solutions, however Maskos overcomes this problem by creating "elastic" variables. Creating these "elastic" variables (commonly called "softening") allows Maskos to lessen the severity of the constraints that prevented the model from finding a feasible solution. These elastic variables are multiplied by penalties for under or over achieving the original range of the constraint. The "elastic" variables with penalty are added to the objective function. Specifically, these "elastic" variables allow Maskos flexibility by selecting which constraints to violate and by how much in order to get a feasible solution. In the end, he successfully solves an integer network model using GAMS which yields a feasible solution for assigning recruits.

Justice [Ref. 3] examines a class scheduling problem with some similarities to the TBS MOS assignment problem. He uses a mixed integer program to minimize the number of waiting days for enlisted Marines at the Marine Corps Communication-Electronics School. His model determines the optimal class schedule and number of students to enroll in each class so student waiting time between classes is minimized.

His model solves a problem that is much more complicated than the TBS problem. Specifically, many Marines are required to attend more than one course at the school in order to be fully trained. Therefore, one of the constraints consisted of Marines

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having to take sequentially ordered classes, i.e., predecessor and successor constraints. Like Maskos, Justice uses a model with elasticity that allows for a penalized violation of constraints that might otherwise lead to infeasible solutions. He further demonstrates that some violations of constraints might be reasonable and would lead to feasible solutions. For instance, a course might have a minimum class size of ten Marines. However, if eight Marines are available to start, then this constraint might be violated with some penalty rather than have the eight Marines wait while another two Marines complete a predecessor course. Elastic variables allow flexibility and slight deviations that are considered acceptable by the user/customer. Thus, appropriately deemed constraints are loosened to yield feasible solutions. Justice eventually utilizes a desktop computer and the General Algebraic Modeling System (GAMS) to develop a class schedule and student class quotas which reduced waiting time in man days by sixty-two percent over the manual method previously used.

In their research article, Blanco and Hillery [Ref. 4] discuss their lessons learned, as well as their experiences of implementing an optimization computer model in the Bureau of Naval Personnel. They develop a desktop model to be used as a decision support system by Navy detailers who manually assign thousands of sailors to thousands of jobs on a monthly basis. This very complex process is a classical military assignment problem. However, the Navy Personnel Assignment branch has complex eligibility rules (e.g., time on station requirements, technical training required), and multiple objectives (e.g., filling technical training school seats in route to assignment, limiting moving costs, and balancing quotas for major fleet commands). Because of the complexity and the fact

that all assignments were done manually, the Chief of Naval Personnel authorized and supported an optimization model for personnel assignment.

Initially, the developers of this model, Blanco and Hillery, were not able to successfully implement a desk-top optimization model. Although mandated and supported by senior leadership in the Navy, the authors failed to solicit input and requirements from the two hundred sailors who actually perform detailing of assignments. As a result, with little input from these users, the model was resisted and not utilized. The authors freely admit to a cardinal error made by many scientists and technology managers. They build a theoretically superior and sound assignment model, but failed to adequately identify what the user or customer truly needed. What the detailers really needed was a flexible system that allowed them to add the human perspective in the assignment of sailors.

Several information technology projects have failed because of a lack of acceptance from the intended users. After realizing their mistake, the authors revised the assignment model by closely working with the intended users to get input and problems identified. This revision was successfully implemented. Blanco and Hillary learned four important lessons. First, any operations research team must listen to the customer and understand their perceived needs. Understanding the real problem and overcoming likely resistance to change is vitally important. Second, the magnitude of any organizational change (e.g., going from a manual to automated assignment process) should be formulated in small increments. One should be careful not try to change too much too soon. People tend to become overwhelmed if the change is very different from current conditions [Ref. 5]. Third, any model or information technology should be tested and

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evaluated early and often by the user so any failings can be corrected early. This results in a user-friendly model with an increased chance of acceptance.

Fourth, coalition building for successful implementation is a must. Senior management, middle management, users, customers, and suppliers should all be included in development and problem formulation. This concept promotes acceptance and validity of any model developed. Additionally, sometimes having a systems advocate within the organization is also beneficial. For example, because the authors were civilians located in San Diego working for the military in Washington, D.C., they were considered outsiders. However, once they included the actual Navy detailers in the process, they won the support of the most vocal opponent in the organization who eventually promoted their model as a good working tool.

B.   NON-MILITARY RELATED STUDIES

In his research paper, Tripathy [Ref. 6] finds a feasible solution to a time-table problem for a one year graduate program involving nine hundred students. A huge scheduling problem existed for the graduate program as the nine hundred students were enrolled in twenty-five different academic paths. Many of these academic paths require the same courses. For example, academic path 1, academic path 3, and academic path 11 may all contain an economics course requirement during the first quarter. But, each of these three academic paths may also contain courses totally unrelated to one another. Therefore, when a course is scheduled, special attention must be paid to ensure that class X is not scheduled during class Y if both classes are required during the same semester. This scheduling problem quickly becomes very difficult due to the large number of

potential schedule combinations that must be avoided. Other constraints included class size, class periods per day, and instructor availability.

This time-table scheduling problem is clearly an integer optimization problem because fractional numbers of students cannot take courses in a fractional time period. Tripathy solves this extremely complex problem utilizing Lagrangean Relaxation. Using this technique, the author relaxes, removes, or modifies constraints, in order to find feasible solutions. Lagrangean Relaxation also allows Tripathy to solve this highly complex optimization problem using simple linear programming.

Tripathy successfully schedules eighty-five percent of the students for all their quarterly classes without any significant violation of major constraints. The remaining fifteen percent experience a scheduling conflict. Some violations of constraints were allowed. For example, instead of only allowing thirty students into a class A, the constraint was relaxed to allow thirty-two students with the assumption that school officials would find two more desks for a classroom and allow the student to instructor ratio to be slightly increased.

Tripathy's only negative comments on his use of the Langrangean Relaxation concerns the large storage requirement for data and the long computational time. However, computer technology and capabilities have improved exponentially since Tripathy's efforts in 1984. Using Lagrangean Relaxation to solve this problem on current desktop computers would prove very viable and fast.

Optimizing flight crew schedules at American Airlines was the subject and research of Gershkoff [Ref 7]. Scheduling flight crews to fleets of aircraft that have two-hundred flights per day while maintaining mandatory constraints imposed by the

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Federal Aviation Administration (FAA) and flight unions is a very challenging endeavor indeed.

The objective of Gershkoff's research was to build a linear programming model that would minimize the cost of flying a published schedule. The schedule was subject to the following constraints: 1) each flight must have a complete crew the entire trip; 2) each flight crew assigned from a home base airport must be returned to the home base airport; 3) each crew must not work more than the maximum allowable number of hours per FAA and union regulations; and 4) the number of flight crew members at each home base airport must not exceed minimum or maximum limits set by American's manpower plan.

Improper or non-optimal scheduling of flight crews is very expensive. Flight crew expenses are the second highest cost for airline flight operations, right behind the cost of fuel. If an airline can minimize these costs, profit should increase.

Flight crew costs are high for many reasons, some of which become constraints in the problem formulation. Union contracts guarantee pay for some minimum number of hours each day or trip regardless of hours worked. For example, a flight crew may be guaranteed eight hours of pay even if the crew only works four hours. The FAA imposes a maximum number of hours that a crew may work to prevent fatigue and ensure a higher level of passenger safety. Mandatory crew rest is a relevant and important factor. Additionally, trips exceeding the maximum allowable workday may force overnight stays by the crew in hotels as well as payment of per diem. This cost can quickly escalate if flight schedules are not optimal. As a result, long costly layovers and short workdays are very expensive to airlines, often costing them millions of dollars.

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To minimize the cost of flight crews, Gershkoff uses a integer linear program to better optimize and schedule flight crews at American Airlines. He built a mathematical model to minimize the cost of pairing flight crews to trips, while ensuring all FAA and union constraints were met. He soon discovered the problem was too large. In order to find a feasible solution, he could not focus on the entire airline. Rather, he broke the problem into segments in which crews are matched to trips that are in sets of two hundred flights per day or smaller.

Gershkoff built a linear program matrix, and uses a microcomputer with a commercial optimizer to find feasible solutions that met the constraints. His improvement on flight crew scheduling resulted in estimated savings of $18 million dollars per year for American Airlines.

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III. ASSIGNMENT OF MILITARY OCCUPATIONAL SPECIALTIES

A. BACKGROUND

The assignment of Military Occupational Specialties (MOS's) to new officers is a very important and sensitive issue for Marine Corps manpower planners, The Basic School, and the individual officer. The primary objective of manpower planners is to provide the appropriate number of trained Marine officers to commanders in the Fleet Marine Force to perform their mission. A secondary objective of the assignment of MOS's is to maintain the morale of the officer corps. Specifically, the MOS assigned to each officer directly effects the next four years of his or her life. An MOS dictates their future assignments and has an indirect impact on future promotion and retention opportunities. Allowing the individual officer as much personal choice as possible is therefore very important.

MOS requirements are determined every fiscal year by the Headquarters Marine Corps Officer Inventory Officer (OIO). These requirements have three key factors that impact how many officers by MOS are required per fiscal year. The three factors are: 1) The Marine Corps Manpower System, 2) Congressional Endstrength Controls, and 3) P2T2 (patients, prisoners, trainees, and transients)

1. Marine Corps Manpower System

The Marine Corps Manpower System is both a closed labor market and vacancy driven system. An officer can only be promoted after a certain number of years of military service and if a vacancy exists for the next higher rank. Unlike the civilian labor market, the military does not allow lateral transfers, e.g., an IBM programmer cannot be hired to be a Major in the Marine Corps. Additionally, the military rank

structure is pyramidal in shape, i.e., more junior officers are required than senior officers. This pyramidal shape is forced by Congressional budget constraints and Marine Corps organizational structure. For example, the Defense Officer Personnel Management Act (DOPMA) limits the number of senior officers (Majors, Lieutenant Colonels, and Colonels). Additionally, the war-fighting table of organization requires many more junior officers than senior officers to lead the many sections, platoons, and companies of the Marine Corps. Therefore, in order to maintain a balanced manpower system, the Marine Corps accesses a large pool of junior officers to meet future rank obligations and MOS billets while at the same time replacing the involuntary and voluntary losses of junior officers that occur every fiscal year. For example, in order to create a single future Colonel (grade O-6, twenty –two years of Marine experience), the Marine Corps would have to recruit twelve Second Lieutenants (grade O-1, zero years of Marine experience). Some of these lieutenants will voluntarily leave the service during the next twenty-two years. Others may be forced to leave the service because of diminishing promotion/billet opportunities.

2. Congressional Endstrength

As part of the annual Defense Authorization Bill, the United States Congress mandates in written law how many officers and enlisted members the Marine Corps is permitted. At the end of each fiscal year, the Marine Corps must report its manning strength to Congress. A one percent tolerance above or below the fixed number is permitted.

The OIO at Headquarters Marine Corps must ensure there is a sufficient supply of

officers with the correct MOS's to fill all vacancies throughout the year. Using historical data, the OIO predicts how many officers above the rank of lieutenant (grade O-1, O-2) will be lost during a fiscal year due to voluntary resignations, involuntary separations, and retirement. Every officer lost must be replaced in order to meet the mandated total officer end strength set in law by Congress. The lost officers are replaced through the promotion of qualified junior officers possessing the prerequisite time in service. As these junior officers are promoted to fill the vacancies of departed senior officers, more junior officers are required to replace the promoted officers. For example, an O-4 (Major) promoted to O-5 would fill a vacant O-5 (Lieutenant Colonel) billet. However, the vacancy caused by the O-4 would require replacement by another officer. Eventually, the vacancy filters down to the need for an additional O-1 (Second Lieutenant) of a certain MOS.

3. P2T2

Prisoners, patients, trainees, and transfers (P2T2) effect the Marine Corps Manpower System and its' endstrength. P2T2 are Marines who count as part of the mandated endstrength; yet, they are not filling manpower billets because they are an incarcerated prisoner, a hospitalized patient, a student in training, or a Marine moving to a new duty assignment. Some P2T2 is obviously inevitable and necessary. However, the Marine Corps must account for P2T2. It must be included in any determination of available manning and MOS requirements even though these Marines are not filling a required MOS billet. Thus, having too many Marines in transition is very costly to the USMC.

B.   ASSIGNMENT OF MOS'S

The assignment of MOS's to officers at The Basic School (TBS) is a two part process. The first part of the process involves the OIO at Headquarters Marine Corps who determines the total fiscal year MOS requirements for each Basic School company. The second part of the process is the actual assignment of an MOS to an individual officer at TBS.

1. Headquarters Marine Corps Process

The OIO uses the Target Force Planning Model to determine the total number of officers by MOS needed per fiscal year. This model, developed by the DSAIC Corporation in 1970, uses a transportation algorithm to calculate the total number of officers, by grade, required for each MOS billet in the Marine Corps. This model also accounts for P2T2.

However, the model only calculates the total number of officers (2nd and 1st Lieutenants) required by MOS to replace the expected annual "cohort losses" from these two ranks due to attrition or promotion to Captain. Each officer "cohort" is simply defined as all Lieutenants who graduated from TBS in a given fiscal year. The average time spent as a Lieutenant in the Marine Corps is 4.2 years. For example, cohort 1999 are all officers who graduated from TBS in fiscal year 1999. These officers will either leave the service or get promoted to Captain in fiscal year 2003. Therefore, at any given time, there are four cohorts of Lieutenants for each MOS. Because four cohorts exist, approximately twenty five percent of all Lieutenants in the Marine Corps either get promoted to Captain or leave the service each fiscal year. Based on this fact, the OIO knows the minimum yearly requirement of Lieutenants for every MOS. However, this

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minimum requirement only considers vacant Lieutenant billets. The OIO must also take into account the losses of all the other officer ranks. Additional Lieutenants must also be accessed to eventually replace senior officers who leave the Marine Corps.

Once the OIO predicts all losses for the officers above the rank of Lieutenant, he multiplies this number by the percentage of Lieutenant billets in each respective MOS. He then adds these new numbers to each of the minimum required officers in each MOS from the Target Force Planning Model, resulting in a new total yearly requirement for each MOS. Table 1, shown on the next page, demonstrates how this procedure works using fictional numbers for MOS 0180. MOS 0180 are ground officers who are trained to handle administrative matters such as correspondence, legal affairs, fitness reports, and awards.

After calculating the yearly total requirement for every MOS, the OIO assigns MOS quotas to each of the six fiscal year Basic School classes. Until last year, the methodology was to simply divide the total yearly requirement by six so that every company had the same number of quotas subject to slight rounding errors. This method is fair but not efficient.

In 1999, the OIO built an Excel spreadsheet model to help determine how many MOS quotas to assign to each TBS class based on MOS school dates and seats available. The objective of the model was to help reduce some of the inefficiency of the "divide by six" method.

Total Requirement for MOS 0180		
Authorized Strength Report (ASR) of MOS 0180*	100	Lieutenants
B-Billets of MOS 0180**	25	Lieutenants
P2T2	25	Lieutenants
Total MOS 0180 required	150	Lieutenants
Annual Cohort (150 divided by 4)*	**38**	Lieutenants
Predicted Losses (all MOS's)		
Captain	100	Marines
Major	50	Marines
Lieutenant Colonel	40	Marines
Colonel	10	Marines
Total Predicted Losses	200	Marines
Percent of all ground officers who are MOS 0180 ****	5.03	
Additional 0180 Lieutenants required 200 x (5.03%)	**10**	Lieutenants
Total Fiscal Year Requirement For MOS 0180 (38+200(5.03%))	**48**	Lieutenants

*   ASR represents actual funded billets in the Fleet Marine Force
**   B-billets are non Fleet billets like recruiting duty
***   Annual Cohort is determined by dividing total requirements by the length of time
         an officer is a lieutenant before being promoted or leaving the service (4.2 years
         rounded to 4 years)
****   This percent is derived by taking the annual cohort of MOS 0180 and dividing
         by the total annual cohorts of all twenty-one ground MOS's

Table 1. Example Of Determining Total Fiscal Year 0180 MOS Requirements

2. The Basic School Process

After the OIO assigns the respective MOS quotas to each company, the company

staff of each Basic School company assumes responsibility. The company staff is

comprised of a Commanding Officer (rank of Major), Executive Officer (rank of

staff interacts daily with the student officers in both the classroom and tactical field environment. They know the student officers' strengths and weaknesses. They also evaluate the student officers in three areas. The first area is leadership. Leadership grades are based on how the student performs in leadership billets in garrison and tactical exercises while leading fellow officers. Academics are the second evaluated area. Grades from standard style exams are given on wide ranging subjects such as military law, administration, and communications. Finally, the third area is military skills. These grades involve performance on such items as marksmanship, land navigation, and physical fitness.

To help decide the MOS in which they are interested, the student officers talk with company staff members who have different MOS's, as well as attend "MOS mixers". MOS mixers are social events where every MOS is represented by actual officers working in the MOS. Students are free to ask questions and get perspective from these officers on what they do for a living.

At approximately the nineteenth week of the twenty-three week basic course, the student officers provide a list of their MOS preferences to the company staff. This list ranks, in order of personal preference, all twenty-one ground MOS's.

Also at the nineteenth week, the company staff receives a lineal ranking of every member of the company based on their grades in the three evaluated areas. The grades are weighted as follows: fifty percent for leadership, twenty five percent for military skills, and twenty five percent for academics. Additionally, the company is broken down into thirds based on the lineal standings, i.e., a top one-third, a middle one-third, and a bottom one-third. The MOS quotas are also divided into thirds. For example, a TBS

company may have twenty-seven slots of the infantry MOS from the Officer Inventory Officer. Each one-third of the company would have the opportunity to seek nine slots.

For many years, TBS has used the technique of dividing a company into thirds to maintain a "quality spread" for the MOS's. The intent of TBS is to prevent all the best performers in a company from populating the glamorous or popular MOS's, thus leaving less glamorous MOS's with solid but not great performers. Good examples are the infantry and ground supply MOS's. Infantry in the Marine Corps is traditionally the most popular and sought after MOS. Ground supply is often the least popular. Therefore, the Marine Corps, as well as TBS, have adopted the rule of dividing all MOS quotas into thirds. This ensures all officers an equitable opportunity for a particular MOS. Moreover, all MOS's, and subsequently the fleet, will have officers of many different abilities and desires serving within that MOS.

With the lineal standings, MOS quotas for each third of the company, and student officers' MOS preference sheets, the company staff starts to assign MOS's to individual officers. They start with the number one ranked officer and work their way to the very last ranked officer. As each student officer on the lineal list appears, the staff looks at his first choice and sees if a slot for that MOS choice is available in that officer's one third of the company. If so, he or she gets the MOS. If not, the staff will look at second, third, and even more choices until a suitable match is found. Additionally, each company staff attempts to assign every officer to one of his top three MOS choices. This attempt is done by trading MOS's. For example, suppose an officer got his second choice of the logistics MOS and the communications MOS was his third choice. Suppose further that another officer received his tenth choice of MOS which was communications. But, on

his preference sheet, his third choice was the logistics MOS. If both officers are in the same third of the company, the staff may switch MOS's between these two officers by reassignment even though one officer is higher in the lineal standing. This procedure is designed to make one person better off without making someone else significantly worse off, i.e., both officers receive one of their top three choices. Historically, TBS achieves a success rate of approximately eighty percent of all officers getting one of their top three choices, Reference[8].

C. MOTIVATION FOR A COMPUTER MODEL

Prior to 1999, the OIO took the total annual MOS quotas and divided them by six. Each of the six yearly TBS classes received equal quotas of all MOS's. Although this method appears to have tremendous equity, the efficiency is very poor. Efficiency for this thesis is defined as assigning MOS's such that time awaiting training for MOS schools is minimized subject to certain constraints.

The methodology of dividing all the MOS quotas by six is highly inefficient because of large waiting times experienced by officers trying to attend MOS schools with limited seating and schedules that did not match graduation dates TBS companies. For example, the Basic Communication Officers Course is only conducted twice a year due to the length of the course as well as other constraints such as equipment and instructors. Therefore, depending upon which TBS company an officer attends, he or she may have to wait six months before starting a school that is six months long. Additionally, some companies can be as much as thirteen percent larger in number of student officers. Therefore, smaller sized companies could have advantages or disadvantages in the assignment of the more prestigious MOS's like infantry, or less prestigious MOS's like

ground supply. Situations like the communications school cause unnecessary and increased time awaiting training. Officers are either forced to endure the wait by filling temporary duty in the vicinity of the school, or they report to their first job assignment inadequately prepared. If filling a temporary job, then the officer is not being used productively in the Fleet billet where he or she is slated. This causes burdens for commanders of operational units because they do not have the correct number of officers to conduct their peacetime or wartime mission. If the officers are sent to their first job without MOS training, then the officers are forced to learn on the job, eventually being sent to the MOS school at a later date. This situation results in lost productivity of the officer and disruptions to the organizations that rate the presence of these officers. Excessive delays due to time awaiting training cause strains on the manpower system of the Marine Corps. The war fighting capability of units without the correct number of officers diminishes. Therefore, the Marine Corps makes every attempt to try to reduce the number of unfilled billets, but cannot of P2T2. P2T2 is similar to a costly overhead account in manufacturing. Overhead should be minimized to maximize profit or minimize production cost. In the Marine Corps, P2T2 represents Marines who are being paid for and counted as part of a Congressionally mandated end strength; however, the Marine Corps is receiving no immediate productivity or benefit. It is unrealistic and foolish to expect zero P2T2 because the Marine Corps will always have Marines attending schools and advanced training. Marines also must execute permanent change of station (PCS) orders. However, efforts must continue towards controlling P2T2. Reducing the amount of time a Marine is unproductive because he or she is awaiting training and not in their normal job is achievable through proactive scheduling.

Scheduling problems such as this fall into the realm of linear programming, making them very suitable for a computer based model.

Based on the need to reduce excessive waiting time, the officer inventory officer recently developed a Microsoft Excel based computer model that attempts to better align MOS school dates and MOS quotas. Some gains in reducing the time awaiting training were realized when the results of the Excel model were implemented. The model developed last year by the officer inventory officer is an improvement over simply dividing all MOS quotas by six. However, this model is still very time consuming because the user must use his best guess, intuition, and experience to find feasible solutions in order to diminish the time awaiting training.

Greatly improved reductions are more likely through a linear programming model. The awesome computing power of today's computers, as well as commercially available linear programming software, means a better solution should be found. Thousands of iterations can now be done in minutes. A computer model to solve this scheduling problem is justified.

The need for such a model is also critical due to the smaller defense budgets over the last few years as well as projected smaller budgets in future years. Smaller budgets mandate the need to save money and keep the manning of operational forces in the Marine Corps at a high rate. One way to accomplish this savings is to decrease P2T2. One contributing factor to this costly P2T2 is time awaiting training from TBS graduates who are enroute to formal MOS education. A computer model could help diminish this P2T2 by solving this classic scheduling problem.

A further reason for a computer model is that it forces the builder of the model to examine this problem in detail. Determining the relevant constraints, variables, and data, requires methodical and careful analysis. This type of analysis might reveal alternatives not yet discovered. For example, a model could allow the user to quickly change or loosen a constraint and see the results. Perhaps a mandated constraint is no longer relevant or as inflexible as Headquarters Marine Corps believed. A good computer model allows the flexibility to change variables, constraints, and data. This flexibility allows one to examine the implications of these changes in an efficient and fast manner.

Finally, a computer model is essential because OIO's rotate from their job every three years. The analysis and learning of each OIO could be incorporated into the model to prevent the loss of corporate knowledge.

IV. MODEL DESCRIPTION

A. MINIMIZING TIME AWAITING TRAINING MODEL

The Minimizing Time Awaiting Training (MTAT) model is a linear

program that optimally assigns TBS officers to MOS classes. It minimizes the

cumulative time all officers wait from TBS graduation until the start of MOS school

while also providing equity of opportunity for MOS selection by TBS officers. The

mathematical notation is the same notation found in the General Algebraic Modeling

System (GAMS) Ref[9] implementation of the linear program described below.

1. INDICES

c   MOS class offering (e.g., 1,2, ...10)

e   extra seat number (1,2, ... 6)

m   MOS (e.g., infantry, logistics, supply...)

t   TBS company (company A, B, C, D, E, F)

2. DATA (units are in parentheses)

$DAYSWAIT_{m,c,t}$ (day) The number of days an officer waits if he graduates from TBS company t and attends class c of MOS m, calculated based on:

         $SCHOOL_{m,c}$ (day) The Julian date that class c of MOS m starts.

         $TBSGRAD_t$ (day) The Julian graduation date for TBS company t.

         $TRAVEL_{m,c}$ (day) The total number of travel and proceed days authorized from TBS in Quantico, Virginia, to MOS school m.

GRAD$_t$ (Marine) The total number of officers graduating from TBS company t.

MINASSIGN$_{m,t}$ (Marine) The minimum desired number of officers from TBS company t to assign MOS m.

MAXASSIGN$_{m,t}$ (Marine) The maximum desired number of officers from TBS company t to assign MOS m.

PENSEAT$_{m,c,e}$ (day/Marine) The penalty to provide an extra seat e to class c of MOS m.

SEAT$_{m,c}$ (Marine) The number of seats in class offering c for MOS m.

TOTAL$_m$ (Marine) The total fiscal year allocation of MOS m for all TBS companies.

3. VARIABLES (units in parentheses)

ldev$_{m,t}$ (Marine) Number of officers desired, but not assigned MOS m from TBS company t.

marine$_{m,c,t}$ (Marine) Number of officers from TBS company t assigned class offering c for MOS m.

udev$_{m,t}$ (Marine) Number of officers assigned MOS m in excess of the desired number, from TBS company t.

extraseat$_{m,c,e}$ (day) One if using extra seat e, for MOS m , class offering c.

4. OBJECTIVE FUNCTIONS

$$\min \sum_m \sum_c \sum_t \text{DAYSWAIT}_{m,c,t} \ (\text{marine}_{m,c,t}) \ + \qquad (1)$$

$$\sum_m \sum_c \sum_e \text{PENSEAT}_{m,c,e} \ (\text{extraseat}_{m,c,e})$$

$$\min \sum_m \sum_t (\text{ldev}_{m,t} + \text{udev}_{m,t}) \tag{2}$$

5. CONSTRAINTS

$$\sum_c \sum_m \text{marine}_{m,c,t} = \text{GRAD}_t \quad \forall\, t \tag{3}$$

$$\sum_t \text{marine}_{m,c,t} \leq \text{SEAT}_{m,c} + \sum_e \text{extraseat}_{m,c,e} \quad \forall\, m,c \tag{4}$$

$$-\text{ldev}_{m,t} + \text{MINASSIGN}_{m,t} \leq \sum_c \text{marine}_{m,c,t} \leq \text{MAXASSIGN}_{m,t} + \text{udev}_{m,t} \tag{5}$$
$$\forall\, m,t$$

$$\sum_c \sum_t \text{marine}_{m,c,t} = \text{TOTAL}_m \quad \forall\, m \tag{6}$$

$$\text{marine}_{m,c,t} \geq 0 \qquad \forall\, m, c, t \tag{7}$$

$$\text{ldev}_{m,t} \geq 0 \qquad \forall\, m, t \tag{8}$$

$$\text{udev}_{m,t} \geq 0 \qquad \forall\, m, t \tag{9}$$

$$1 \geq \text{extraseat}_{m,c,e} \geq 0 \quad \forall\, m, c, e \tag{10}$$

This first objective function is a measure of *efficiency*, in units of Marine Waiting Days. The *efficiency* of a solution provides a relative indication of how well all MOS quotas assigned to Basic School companies align with MOS school dates and seats available. Marine Waiting Days of a graduate from a TBS company is the number of days between graduation of the TBS company and the start of the MOS class allowing for travel.

The Basic School in conjunction with Headquarters Marine Corps sometimes graduates officers early in order to meet an MOS class start date. Marine Waiting Days

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for early graduation is two waiting days for every one day an officer leaves before his TBS graduation date. Currently, the model allows an officer to graduate a maximum of twenty-one days early penalized as forty-two Marine Waiting Days. Both the penalty and maximum number of days to graduate early can be changed.

The first objective function also penalizes for extra seats that are added to MOS schools. Currently, the model allows up to six extra seats per MOS class, but penalizes differently for the number of added seats. Because adding one or two extra seats is relatively easy, the model uses a penalty of 0.5 Marine Waiting Days. A penalty of 0.5 implies, when a choice exits, it is better to add one or two extra seats than to have a TBS graduate wait one more day. Because acquiring more than two extra seats per class is exceedingly difficult, the model currently uses a penalty of six Marine Waiting Days for every additional seat in excess of two.

The second objective function minimizes the number of officers who fall outside the desired minimum and maximum assignment quotas for each MOS. Headquarters Marine Corps dictates these quotas to ensure some sort of *equity*. This policy ensures all officers in all six TBS companies have some opportunity to compete for any MOS. However, the number of quotas is subject to interpretation by Headquarters Marine Corps. Currently, the minimum and maximum number of quotas for each MOS per Basic School company is eight percent and 20 percent respectively Ref [10]. The model allows the decision-maker to easily change the minimum and maximum.

Constraint (3) ensures every officer in each TBS company has a MOS and MOS class assignment.

Constraint (4) ensures adherence to MOS class seat capacity. The constraint is elastic, allowing for extra seats to be added.

Constraint (5) ensures the satisfaction of minimum and maximum TBS company MOS quotas.

Constraint (6) ensures the fiscal year quotas for all MOS's are filled. Headquarters Marine Corps determines and mandates MOS quotas to meet congressionally required end strength.

The final constraints, equations (7) through (10), enforce non-negativity.

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V.   OLD MODEL VERSUS NEW MODEL RESULTS

A.   HEADQUARTERS MARINE CORPS EXCEL MODEL(OLD MODEL)

As discussed previously, the Officer Inventory Officer (OIO) at Headquarters Marine Corps built an Excel spreadsheet (old model) to help better align MOS school seats with MOS quotas at The Basic School. The model allows the user to "best guess" possible combinations of MOS quotas for TBS in an attempt to minimize time awaiting training. The model utilizes travel time, TBS graduation dates, and MOS class offering dates to calculate the days awaiting training for all officers and all MOS classes. The model also readily displays the maximum number of seats in order to prevent violation of the class size constraint. The old model also sums all the MOS assignments ensuring every officer has a class date and an MOS. Unfortunately, the model completely relies on the intuition and experience of the user to find feasible solutions. Additionally, the user must manually input each new parameter in order to find improved solutions. This is very cumbersome, time consuming and not exhaustive. An optimal solution might be overlooked. As compared to the new model introduced in this thesis, the old Excel model fails to take advantage of currently available software solving tools such as GAMS. GAMS has the ability to examine the entire range of feasible solutions.

Table 2 summarizes the days awaiting training from the Excel model. This table will be used for comparison with the results of the new model later in the chapter. The Excel model determined MOS quotas for each TBS class for fiscal year 1999. Every officer was assigned an MOS as well as an MOS class. Some classes required additional seats. However, no more than two seats were ever added to any one MOS class.

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MOS*	DAYS AWAITING TRAINING
adj	1364
staplt	317
humint	552
sigint	542
airintel	878
infantry	1384
log	5033
comm	5930
arty	2262
engineer	689
armor	451
amtrac	799
supply	2411
finance	1317
pao	321
mp	1365
amaint	1137
asupply	1118
airsupport	830
airdefense	704
atc	94
nfo	360
pilot	520
Total**	30378
Man Years***	83.23

*   MOS abbreviations are described in Appendix A
**   Total sum of all MOS's waiting days
***   **Man Years** equals **Total** ÷ 365 days/year

Table 2. Summary Of Days Awaiting Training As Calculated Using Old OIO Excel Model

These results shown in Table 2 consider the "efficiency", or how well MOS quotas assigned to TBS companies align with MOS school dates and available seats.

"Equity", or fair distribution of quotas for each MOS as defined by HQMC, for this model is the responsibility of the decision maker who assigns MOS quotas to each TBS company. It is therefore hard to compare "equity" of the new and old models.

B. MINIMIZING TIME AWAITING TRAINING MODEL (NEW MODEL)

The Excel Model was considered a vast improvement over the original, simple technique of dividing all the MOS quotas by six and assigning these quotas to the six TBS companies. Unfortunately, no data was calculated or maintained from previous fiscal years concerning the number of days awaiting training, Ref[11]. However, according to manpower planners, the Excel model significantly diminished the days awaiting training compared to the highly inefficient "divide by six method". But, the Excel model does not exploit the immense computing power available in current linear programming software to examine different feasible solutions.

Using the Minimizing Time Awaiting Training (MTAT) Model built in GAMS, a desk top personal computer executed several model runs with different input data and only required ten seconds per run on a 266 megahertz Pentium II desktop computer. The changes to input data included the minimum and maximum number of MOS quotas for each TBS company. These were changed to simulate decision maker variability. Furthermore, the penalties for graduating officers from TBS early or adding extra MOS class seats also varied. All of the runs proved the superior flexibility of the model to help decision makers evaluate the feasibility of solutions and examine the impact of days awaiting training due to varying relevant inputs.

Specifically, the model provides the number of officers that should be assigned to each MOS for each TBS company. It also provides total days spent waiting for each

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MOS school, number of officers assigned or not assigned the required MOS quotas for each company, the number of extra seats for each MOS class, and number of officers to graduate early from TBS. Tables 3a and 3b show a given set of parameters and the model results in terms of "efficiency" and "equity". All runs resulted in feasible solutions without violating any constraints . These six model runs show how a decision maker can compare different "efficiency" versus "equity" combinations. Figure 1 is an example of how the model runs can be presented so that decision makers can examine tradeoffs between "equity" and "efficiency".

Minimum percent of each MOS quota desired for each company	Maximum percent of each MOS quota desired for each company	Penalty in days for graduating early from TBS. Penalty per day early.	Penalty in days for adding 1 or 2 extra seats to an MOS class
8 %	20%	2	0.5

Table 3a. Input Data For MTAT Model Runs

	Max Deviation * Allowed (Equity)	Total Days Awaiting Training (Efficiency)	Total Man Years**
Run 1	9999	14042	38.5
Run 2	200	15925	43.6
Run 3	100	18428	50.5
Run 4	50	20369	55.8
Run 5	10	22662	62.1
Run 6	7	23202	63.6

* Max Deviation is the maximum number of officers who are under or over the desired number of MOS quotas for all TBS classes
** Total Man Years = Total Days Awaiting Training ÷ 365

Table 3b. Results Of MTAT Model Runs
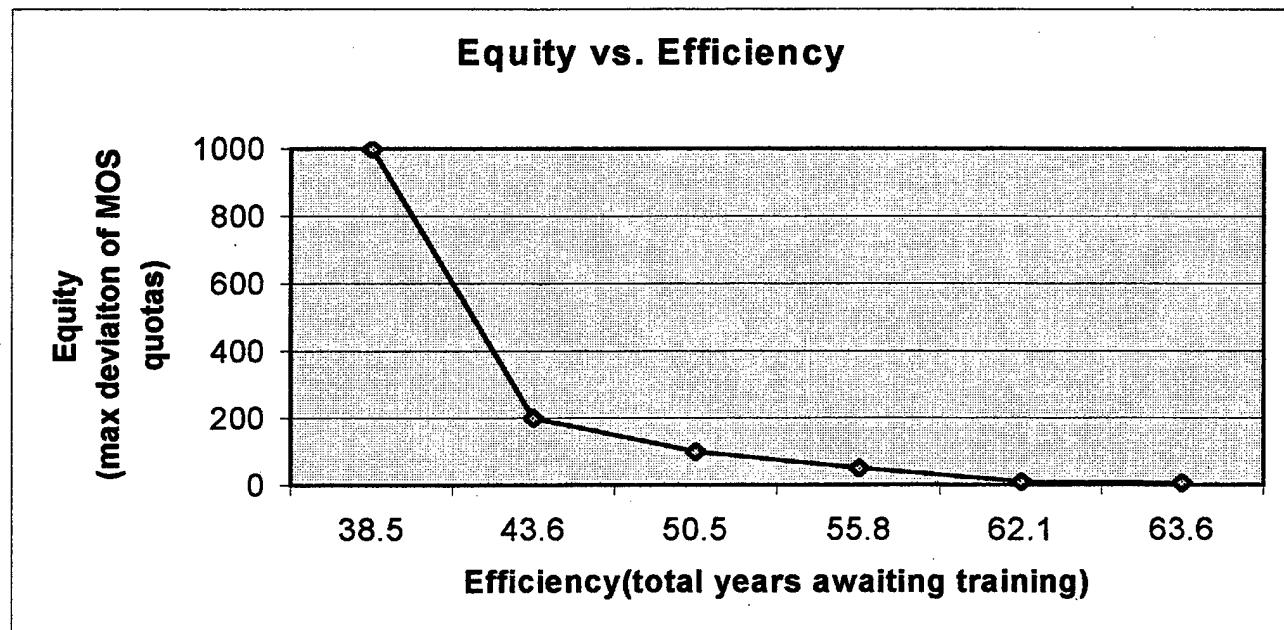
Figure 1. Tradeoff Between Equity And Efficiency

In every model run, regardless of the "equity" used, the "efficiency" was far superior to the Headquarters Marine Corps Excel model. The savings in "Man Years" is shown in Table 3c. The definition of a Man Year is one officer serving in an authorized billet for a complete year. A savings of one Man Year in time awaiting training is equivalent to having one more officer serving in an operational billet for a year instead of in P2T2. Table 3c shows using the MTAT model to conduct thousands of iterations is a substantially improved solution to the time awaiting training problem as compared to the old model.

Run	Old Model (Man Years)	MTAT Model (Man Years)	Savings (Old –MTAT) (Man Years)
1	83.23	38.47	44.76
2	83.23	43.65	39.60
3	83.23	50.49	32.74
4	83.23	55.80	27.42
5	83.23	62.09	21.14
6	83.23	63.57	19.66

Table 3c. Savings In Man Years From Using MTAT Model

C. FEASIBILITY OF RESULTS FROM MTAT MODEL

After executing numerous model runs, the results indicate that the model has

tremendous application for use by Headquarters Marine Corps.   First, the model can

force the number of officers required, but not assigned to a particular MOS, to be very

small. Specifically, Table 4 shows that on one typical model run, only five officers were

not assigned to the required MOS quotas. The five officers effected were members of

two of the six TBS companies; specifically, Companies A and B. The other four,

Companies C, D, E, and F, experienced no such assignment problems. The other table,

Table 5, shows the number of officers assigned an MOS in excess of the required quota

for the same run. Only one of the six TBS companies, Company D, experienced this

problem.

MOS	Number Of Officers From TBS Company A	Number Of Officers From TBS Company B
atc	0	1
nfo	1	1
pilot	1	1

Table 4. Number Of Officers Deviating Below MOS Quotas, All Companies, FY 99

MOS	Number Of Officers From TBS Company D
atc	2

Table 5. Number Of Officers Deviating Above MOS Quotas, All Companies, FY 99

These small numbers are well within an acceptable tolerance. In fact, mismatches are considered normal. Headquarters Marine Corps never achieves one hundred percent of their assignment quotas due to discharging officers for administrative and disciplinary reasons. As a result, MOS quotas are never perfectly filled. As stated earlier, Headquarters Marine Corps' main goal is to meet Congressionally mandated endstrength. However, it is acceptable to manpower planners to allow each MOS to be over or under the requirement by one or two officers. Fortunately, a decision maker can always manipulate the model to achieve the right number of officers in an MOS if that MOS is critically short in manpower. The flexibility to manipulate the model for any given situation is a superb strength of this new model. The ability to quickly vary inputs, execute additional runs, and conduct a sensitivity analysis demonstrates this flexibility.

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Another output of the model which is useful are the "extra seats" required for each MOS. These extra seats are part of an "elastic" constraint that allows the model to deviate with penalty from the original constraint of MOS classroom seat capacity. Allowing this constraint to be elastic enabled the model to find feasible and realistic solutions for MOS assignments. Generally, most MOS's required less than three additional seats per MOS class. The exceptions to this are the infantry and communication MOS's. However, the infantry MOS is the one MOS in which more than one or two seats are easily added. As mentioned previously, adding more than one or two extra seats to most MOS classes is increasingly difficult, especially when the schools are other military service schools. However, the Infantry Officer Course (IOC) is a Marine Corps school co-located with TBS. TBS provides all the equipment, instructors, and training support to IOC. Historically, this course sometimes adds five to ten extra seats. For example, aviators, who endured a long wait to start flight school in Florida attended the Infantry Officer Course as a career broadening experience. IOC easily accommodates an extra ten officers without requiring additional equipment, classroom, or instructor capacity. Therefore, the results that require this apparently large number of extra seats, is not an infeasible solution. Table 6 on the next page is a summary of all the extra seats required for a sample model run.

MOS	Number of classes FY 00	Total number of extra seats	Average number of extra seats per class*
adj	3	2	0.66
infantry	5	29	5.8
engineer	6	6	1.0
finance	5	3	0.6
airsupport	6	6	1.0
staplt	5	8	1.6
log	6	3	0.5
armor	7	6	0.85
pao	5	3	0.6
airdefense	4	4	1.0
comm	2	6	3.0
amtrac	3	2	0.66
amaint	5	6	1.2
atc	7	6	0.85
airintel	6	9	1.5
arty	4	3	0.75
supply	4	6	1.5
asupply	3	2	0.66
signint	6	4	0.66

* Decimal seats should be rounded to nearest whole seat for actual planning

Table 6. Number Of Extra Seats By MOS For Typical MTAT Model Run

As shown by the results in Table 6, the number of extra seats required is within acceptable limits in all cases except one. The one exception is the communications MOS, abbreviated comm. Communication Officer School cannot accommodate any extra seats in either of the two yearly classes. The school has a fixed, maximum quota of fifty students per class, Ref [12]. The maximum quota is a function of an equipment constraint. The school has only fifty computer workstations that play a significant part in the course of instruction. Although the model produced these results, the decision maker can easily override the results.

D. MTAT MODEL FLEXIBILITY

Some of the results, although feasible, reveal areas of potential concern. Because the model is flexible enough to provide decision makers full control over inputs, the model will accept these inputs and still provide the best feasible solution. Table 7a shows the input parameters used on a particular set of model runs. Table 7b shows results that might cause concerns based on the parameters used in Table 7a.

INPUT PARAMETER	PARAMETER VALUE	UNITS
Maximum Number Of Days To Graduate Early	21	Days
Penalty For Each Day Graduating Early	2	Days

Table 7a. Input Parameters For First Set Of Model Runs

MODEL VARIABLE	MODEL RUN RESULTS
Number of Officers Sent Early	172
Percentage of All Officers Sent Early *	17.4%
Total Number of Officer Days Sent Early	1253
Average Number of Days Each Officer Is Sent Early	7.3

* Percentage is calculated by dividing 172 by the fiscal year total of all officers assigned any MOS (989)

Table 7b. Number Of Officers Sent Early From TBS To Meet An MOS Class Date

Specifically, the number of officers sent early might be a concern for The Basic School (TBS). Although TBS is familiar with graduating small numbers of officers early to meet a school date, having seventeen percent of all officers graduate early might cause an administrative and logistical burden for the school.

The reason for the potential burden is quite simple. Specifically, during the last two to three weeks of any TBS company, much time is devoted to returning military equipment to supply, replacing lost supply items, completing medical and dental requirements, finishing uniform fittings, and making up of any failed exams or missed events. To graduate such a large number of officers early is an issue that might pose a problem for TBS. The issue would require careful analysis and planning outside the model to determine if graduating one hundred seventy two officers early is truly feasible. However, this entire situation may be avoided if certain input parameters in the model are changed. Specifically, decreasing the number of days an officer graduates early and/or increasing the penalty for each day leaving early will eliminate the issue. Tables 8a and 8b show the flexibility of the model and the reduction of the burden on TBS.

INPUT PARAMETER	PARAMETER VALUE	UNITS
Maximum Number Of Days To Graduate Early	7	Days
Penalty For Each Day Graduating Early	3	Days

Table 8a. Input Parameters For Second Set Of Model Runs

MODEL VARIABLE	MODEL RUN RESULTS
Number of Officers Sent Early	102
Percentage of All Officers Sent Early *	10.3%
Total Number of Officer Days Sent Early	343
Average Number of Days Each Officer Is Sent Early	3.4

* Percentage is calculated by dividing 102 by the fiscal year total of all officers assigned any MOS (989)

Table 8b. Number Of Officers Sent Early From TBS To Meet An MOS Class Date

As shown in the Table 8b, a reduction of early graduates equaling seventy officers occurs by simply modifying two input parameters. However, this reduction also occurs in the form of a tradeoff. The increase in the penalty for graduating early, as well as the decrease in the number of days permitted to graduate early, caused a large increase in the total days awaiting training. Table 9 is a comparison between the two sets of model runs. It is very clear from these results that this model is very powerful and flexible in determining acceptable solutions.

Model Run	Total Days Awaiting Training	Officers Sent Early	Total Officer Days Sent Early	Extra Seats
RUN 1*	23202	172	1253	123
RUN 2**	26457	102	343	124

* Run executed with maximum days allowed to graduate early of 21 days, penalty of 2 days for every day early
** Run executed with maximum days allowed to graduate early of 7 days, penalty of 3 days for every day early

Table 9. Comparison Of Model Runs For Officers Who Graduate Early From TBS

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VI.   CONCLUSIONS AND RECOMMENDATIONS

A.   CONCLUSIONS

The MTAT built in General Algebraic Modeling System software proves itself superior to the Excel spreadsheet model (old model) currently used by manpower planners at Headquarters Marine Corps.

The MTAT model is extremely flexible and fast. It easily accommodates changing parameters that decision makers may like to investigate in order to change a manpower policy. Sensitivity Analysis is also very easy with this model. Specifically, the total number of TBS graduates per company, graduation dates for TBS companies, and total yearly requirements for each MOS are easily modified. After any modification to these parameters, decision makers can run the model and receive new results in about twenty seconds. Additionally, the MTAT model contains easily modified tables for other parameters like minimum and maximum number of Marines with specific MOS's desired from each TBS company, MOS class start dates, and MOS class seat capacities. If a situation arises in which any of these parameters need to be increased or reduced, decision makers can easily make changes to the model and see new possible combinations of "efficiency" and "equity" for MOS allocations. Finally, the model contains elastic constraints with penalties that are also easily modified to reflect a changing manpower environment. For example, the model might determine the need to graduate a large number of officers early from TBS in order to meet MOS school start dates and reduce P2T2. If graduating a large number of officers early from TBS creates an administrative burden on TBS, decision makers can quickly modify the model's proposed solution. They can easily increase the penalty for graduating early as well as

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tighten the constraint on the number of days allowed to leave early. Decision makers can make these simple changes, run the model, and review the new solutions in about two minutes to see the impact of any proposed change or proposed policy.

The MTAT model is also extremely efficient due to the exhaustive mathematical procedures performed by the software and computer. As shown in Chapter V, the MTAT model outperformed the old model in all aspects including minimizing the time awaiting training for the same given parameters and constraints. Several different model runs were executed to give different combinations of "efficiency" and "equity" in MOS allocation. Table 10 shows the immense savings in "Man Years" for several new model runs compared to the old model used for actual fiscal year 1999 MOS allocation.

Run*	Old Model (Man Years)	MTAT Model (Man Years)	Savings (Old –MTAT)) (Man Years)
1	83.23	38.47	44.76
2	83.23	43.65	39.60
3	83.23	50.49	32.74
4	83.23	55.80	27.42
5	83.23	62.09	21.14
6	83.23	63.57	19.66

*   For the new model, each succeeding run was modified to reflect a smaller allowable deviation in the number of officers who were under or over the desired quota for all MOS's; each run consists of thousands of iterations.

Table 10.   Comparison Of Results From Old Model and MTAT Model

B. RECOMMENDATIONS

First, Headquarters Marine Corps should adopt this model as a primary tool to assist the Officer Inventory Officer in assigning MOS allocations to The Basic School. The model's versatility and flexibility make it ideal for determining optimal MOS quotas for The Basic School so that time awaiting training is minimized while also ensuring the goal of equitable distribution of MOS's is met. The model is also superb for sensitivity analysis. A decision maker can quickly input numerous scenarios. The model executes the scenarios resulting in vastly superior solutions in minimal time compared to the Excel spreadsheet (old model) currently used.

Second, Headquarters Marine Corps (HQMC) should invest in linear programming software for use by the Officer Inventory Officer. Ideally, the General Algebraic Modeling System (GAMS) software already in the Installations and Logistics section at HQMC should be licensed for use by the Officer Inventory Officer. This would allow the new model to be used as already built. However, other commercially available mathematical software such as Microsoft's Premium Solver Plus for Excel might also be an option. If another software is chosen, the model could easily be modified to suit any software language. The mathematical formulation of this model is purposefully designed to be implemented to any optimization software.

Third, Headquarters Marine Corps should develop cost models to allow decision makers to weigh tradeoffs between graduating officers early and acquiring extra seats versus allowing larger amounts of time awaiting training.

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LIST OF MILITARY OCCUPATIONAL SPECIALTY ABBREVIATIONS

adj   adjutant

airdefense   air defense

airintel   avaition intelligence

airsupport   air support control

amaint   avaition maintenance

amtrac   amphibious assault

armor   armor

arty   field artillery

asupply   aviation supply

atc   air traffic controller

comm   communications and data systems

engineer   engineer

finance   financial managment

humint   human intelligence

infantry   infantry

log   logisitics

mp   military police

pao   public affairs

signint   signal intelligence

staplt   scout sniper platoon

supply   supply

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